

Cartographical aspects of Martian moons modelling

Ekaterina Grishakina*, Evgeniy Lazarev**, Maria Lazareva*

* Lomonosov Moscow State University, Geographical, chair on Cartography and geoinformatics, Moscow, Russia

** Sternberg State Astronomical Institute, Lunar and Planetary Research - Moscow, Russia

Abstract. We created hypsometric map and 3D-models of the Martian satellites. For its modeling we used digital elevation models (DEM) with 0,5 degree resolution for Phobos (Willner et al. 2010) and 5 degree for Deimos (Thomas, 1993). The map of Phobos and Deimos hemispheres was compiled in orthographic projection at a scale 1:60 000. 3D-models of Martian satellites were created by extrusion the three-dimensional body from the sphere of a fixed radius according to elevation values from DEM. The special color height scale with the equal interval of 500 m was designed with respect to the real colors of the satellites' surface. Suggested techniques of mapping and modelling could be applied for any celestial body with irregular shape for that we have DEM with a determined precision.

Keywords: 3D modeling, hypsometric maps, planetary cartography, planetology

1. Introduction

Phobos orbits round about 9378 km from the center of Mars and Deimos – 23500 from the center of the planet. These celestial bodies have irregular shape and there are different ways to model their form and surface. Hypsometrical maps and three dimensional models are one of the most significant components of Solar System thematic cartography and result from digital terrain models (DTM) processing. They give possibilities to investigate different relief features, to develop space missions including landing on celestial bodies, and to find out space object origin and geology. It is important in popularization of space science and can be used in educational work.

2. Digital terrain models

There are several digital terrain models of Martian satellites based on different shape models of Phobos (Turner 1978, Thomas 1989, Duxbury 1991, Simonelli et al. 1993, Willner et al. 2010, Zubarev et al. 2012) and Deimos (Duxbury & Callahan 1989, Thomas 1989, Thomas 1993). Some parameters of these models represented in *Table 1*. Note that only the most up-to-date Phobos models were used to generate DTMs. Elder Phobos and all Deimos models are shape ones and contain mere a few hundred control points.

Table 1. Shape models of Martian satellites.

Model (Phobos)	Control points	Method	Accuracy, m	Resolution of DTM, m/pixel
Turner 1978	260	Control points	500	
Thomas 1989		Limb observations	150 - 300	
Duxbury 1991	315	Control points	74 - 900	
Simonelli et al. 1993	2x2 degree grid	Control points and limb observations	50	400
Willner et al. 2010	665	Control points	10 - 80	100
Zubarev et al. 2012	800	Control points	11	50-100
Model (Deimos)				
Duxbury & Callahan 1989	53	Control points	75	
Thomas 1989		Limb observations	30 - 100	
Thomas 1993	5x5 degree grid	Control points and limb observations	100 - 200	

For our maps and 3D-models we used digital elevation models (DEM) with 0,5 degree resolution (~100 m/pixel) for Phobos (240 747 object points) (Willner et al. 2010) and 5 degree (~400 m/pixel) for Deimos (2700 object points) (Thomas 1993). Using of these DTMs are conditioned by

combination of several factors: regular covering of entire satellites' surface, sufficient accuracy and data accessibility.

For mapping we used bi-axial ellipsoids as a reference surface although three-axial ones with radii of $13,0 \times 11,4 \times 9,1$ km for Phobos and $7,8 \times 6,0 \times 5,1$ km for Deimos are recommended by the IAU (Archinal et al. 2011). The heights on Phobos and Deimos are referenced to spheres of mean radii 11,1 and 5,77 km respectively. Heights were deriving from DTMs by (Willner et al. 2010) and (Thomas, 1993). Using different vertical (sphere) and horizontal (2-axial map) references for cartographical representation was conditioned on reference of source DEM (sphere) and not-spherical form of Martian satellites' hemispheres referenced to bi-axial ellipsoids.

3. Processing and modelling

There are some aspects in mapping the surfaces of Martian satellites Phobos and Deimos. We can distinguish three main cartographical factors influencing on mapping and modeling such celestial bodies: 1) small sizes and irregular shape (it influences on coordinate system and projection) 2) typical relief features (they should be distinguished) 3) difficulties in obtaining and processing of remote sensing data (accuracy depends on it). Considering these aspects we created hypsometric maps and 3D-models of the Martian satellites.

3.1. Hypsometric maps

The Phobos and Deimos relief map (*Figure 1*) was compiled in orthographic projection (Shibanova, 2011) and published in 2012 (Lazareva, 2012). Orthographic projection is perspective one with center in infinity and therefore it fits for mapping celestial bodies (Bugaevsky & Tsvetkov 2000). It is important, that in ArcGIS the projection named Orthographic could be working only on a sphere, therefore we used projection named Local Cartesian, to be the same as the Orthographic projection, but supported on spheroids and spheres.

As the Moon both Phobos and Deimos always face only one side to the planet since their rotation periods are the same as the period of their orbits rotation. The central longitudes of the hemispheres are 0 and 180 degrees being corresponded to the satellites' nearside and farside respectively. So the map grids were derived from the best-fitted biaxial ellipsoids $11,2 \times 9,1$ km for Phobos and $6,0 \times 5,1$ km for Deimos.

The special color height scale with the equal interval of 500 m was designed with respect to the real colors of the satellites surface (*Figure 2*). A scale of

1:60, 000 was selected for the map, which results in an acceptable resolution of 11.8 pixel/mm (300 dpi) for A1 format hardcopy prints. All IAU approved Phobos and Deimos surface features names (17 craters, Lagado Planitia, Laputa Regio and Kepler Dorsum on Phobos and 2 craters on Deimos) (Gazetteer...) are set both in Latin and in Russian variations. The map was compiled using the ESRI ArcGIS Desktop software.

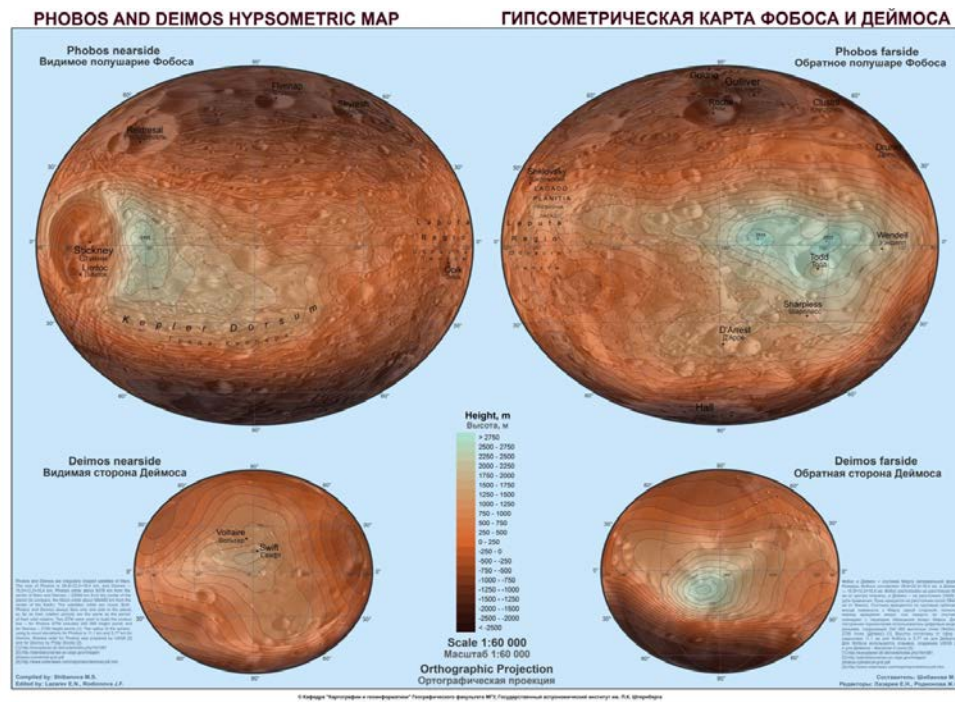


Figure 1. Phobos and Deimos relief map.

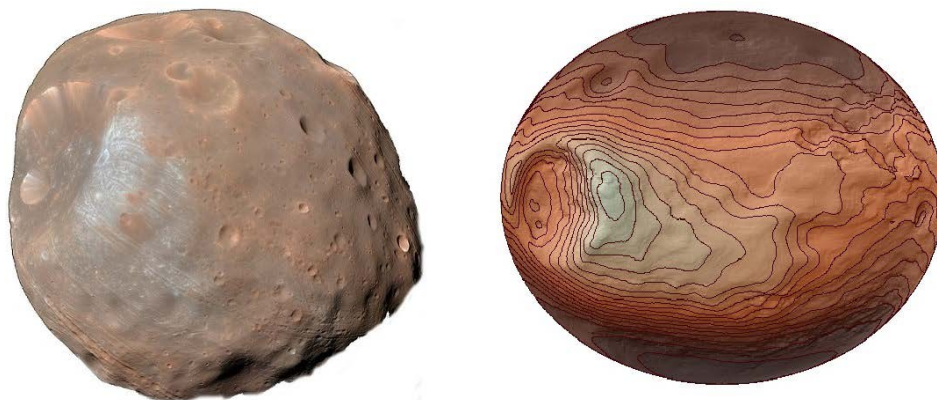


Figure 2. Phobos map (leading side) (left) and an example of one HiRISE (Mars Reconnaissance Orbiter) observation (right).

3.2. 3D models

The first step of 3D-modelling is extrusion the three-dimensional body from the sphere of a fixed radius according to elevation values from DEM. Next, global mosaics of Phobos (Stooke 2011, Thomas 1989) and Deimos (Stooke 2011, Thomas 1989) and the topographic textures with contours having been created in advance were overlayed upon the 3D-figure. 3D-models of Phobos (*Figure 3*) and Deimos (*Figure 4*) were created using the Autodesk 3Ds max software.

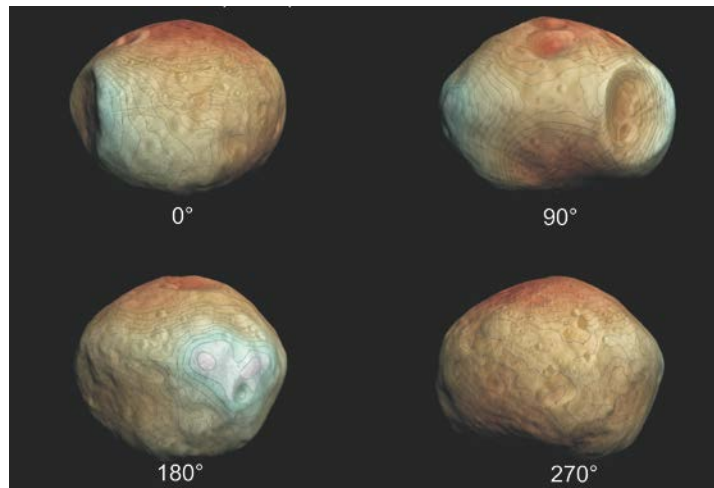


Figure 3. 3D model of Phobos (clockwise from upper left: nearside, leading side, farside, trailing side)

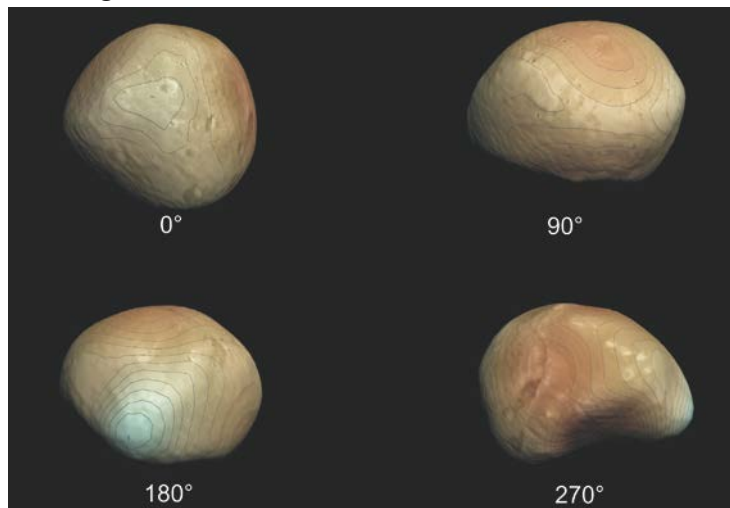


Figure 4. 3D model of Deimos (clockwise from upper left: nearside, leading side, farside, trailing side)

4. Conclusion

Suggested techniques of mapping and modelling could be applied for any celestial body with irregular shape for that we have digital elevation model with a determined precision and space imagery.

References

- Archinal B, A'Hearn M, Bowell E, Conrad A, Consolmagno G, Courtin R, Fukushima T, Hestroffer D, Hilton J, Krasinsky G, Neumann G, Oberst J, Seidelmann P, Stooke P, Tholen D, Thomas P, Williams I et al. (2011) Report of the IAU Working Group on cartographic coordinates and rotational elements: 2009. *Celest. Mech. Dyn. Astron.* 109:101-135.
- Bugaevsky L, Tsvetkov V (2000) *Geoinformatsionnie sistemi*. Zlatoust, Moscow.
- Duxbury T (1991) Analytic model for the Phobos surface. *Planet. Space. Sci.* 39:355-376.
- Duxbury T, Callahan J (1989) Phobos and Deimos control networks. *Icarus* 77:275-286.
- Gazetteer of Planetary Nomenclature. <http://planetarynames.wr.usgs.gov/> (Accessed 15 April 2013)
- Lazareva M (2012) *Kartografirovenie reliefa sputnikov Marsa*. LAP Lambert Academic Publishing, Saarbrücken.
- Shibanova M, Lazarev E (2011) Mars moons relief mapping and modelling: problems and solutions. *EGU General Assembly 2011 Geophysical Research Abstracts* 13:6822.
- Simonelli D, Thomas P, Carcich B, Veverka J (1993) The generation and use of numerical shape models for irregular solar system objects. *Icarus* 103:49-61.
- Stooke P (2011) Stooke Small Bodies Maps V1.0. MULTI-SA-MULTI-6-STOOKEMAPS-V1.0. NASA Planetary Data System.
- Thomas P (1989) The shapes of small satellites. *Icarus* 77:248-274.
- Thomas P (1993) Gravity, tides, and topography on small satellites and asteroids: application to surface features of the Martian satellites. *Icarus* 105:326-344.
- Turner R (1978) A model of Phobos. *Icarus* 33:116-140.
- Willner K, Oberst J, Hussmann H, Giese B, Hoffmann H, Matz K-D, Roatsch T, Duxbury T (2010) Phobos control point network, rotation, and shape. *Earth Planet Sc. Lett.* 294:541-546.

Zubarev A, Nadezhdina I, Patraty V, Shishkina L, Zharov O, Zharov A, Oberst J
(2012) Phobos Control Point Network and Librations. EPSC Abstracts 7:
EPSC2012-238-2